Neue Entwicklungen beim Formhärten
New Press Hardening Developments

13. Werkstoff-Forum
HANNOVER MESSE 2013
Date: 09/04/2013

Speaker: Dr.-Ing. Sven Hübner
Initial Situation: Blank Heating for Press Hardening

Continuous Annealing Furnace

- Length up to 40 m
- Investment up to 1.5 Mio. €
- Mostly used in continuous-running operation
- High energy consumption
- Thermal inert
- Only slow process control possible
- Undesired heating of periphery
- High maintenance expenditure

Conductive Heating

- Low required space
- Low investment
- No need for continuous operation
- Low energy consumption
- Effective fast process control possible
- Only heating of the blank
- Variable heating strategies

Source: Schwartz GmbH
Heating Concept for Form Blanks

Rectangle blank:
Homogeneous voltage distribution
→ Homogeneous heating

Form blank:
→ Exact homogeneous voltage distribution
→ Principle is transferably for arbitrary blank geometries

Layout
1. Split in rectangularly and trapezoid zones
2. Additional staircase-shaped contacting in trapezoid zones
3. Cooling of hotspots with compressed-air
Transformer Contact and Switching Sequence of the Electrodes

Programmable Logic Control (PLC):

a) Switching voltage at pneumatic valve
b) Waiting time (measuring by pressure switch)
c) Control signal to thyristor -> transformer on

-> pressing of electrodes
-> shifting time valve + kinematics + pressure buildup
-> secondary current flow

sequence, exemplary

<table>
<thead>
<tr>
<th>cycle</th>
<th>zone</th>
<th>T0</th>
<th>T2</th>
<th>T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3</td>
<td>E2 + E6 staircase</td>
<td>E2 + E7 staircase</td>
<td>E2 + E3 basis</td>
</tr>
<tr>
<td>II</td>
<td>1 2</td>
<td>E1 + E2</td>
<td>E3 + E4</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td></td>
<td></td>
<td>as above</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td></td>
<td></td>
<td>T = 650°C</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td></td>
<td></td>
<td>T = 950°C</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td></td>
<td></td>
<td>T = 950°C</td>
<td></td>
</tr>
</tbody>
</table>

start:
T = 20°C
T = 350°C
T = 650°C
T = 950°C

© Leibniz Universität Hannover, IFUM, Prof. Dr.-Ing. B.-A. Behrens
Dr.-Ing. S. Hübner
Connection Diagram

- L1
- L2
- L3

PC

- PLC controller
- thyristor power stage
- transformers
- electrodes and blank zones
- pyrometer

- T_{\text{ist,0}}
- U_{\text{St,0}}
- T_{\text{soll,0-2}}
- \text{Y}_{\text{max,0-2}}

- 8 \text{ bar}
- 1-9

- pneumatic valves
- electrodes

- OPC-server

- profibus joint

- profibus

- thyristor-controller 0
- thyristor-controller 1
- thyristor-controller 2

- PLC

- RS232 converter
Cooling Water Diagram

flow
return

control box

thyristor
power stage

thyristor-
controller 0

thyristor-
controller 1

thyristor-
controller 2

U_{th,2}

transformers

T0

T2

T1

electrodes

E1

E2

E3

E4

E5

E6

E7

E8

side panel

current bar

electrodes

side panel

current bar
Plant for Conductive Heating of Form Blanks

staircase electrode (welding tongs)  frame  pyrometer  air regulator and distributor compressed-air jet nozzle  control box

pneumatic cylinder  electrode  PC

cooling water distribution board

**technical data:**
- 460 kVA – 50 % duty cycle
- primary: 400 V 1 kA
- secondary: 30 V 15 kA
Heating Zone

- pneumatic cylinder
- staircase electrode (welding tongs)
- compressed-air jet nozzle
- electrode
- thermal insulating blank
- blank
- ceramic deflection barricade
- current strip
Compressed-air Cooling

- **Intense cooling of lokal hotspots** because of the large current density in the current discharge zone at the staircase electrode.
- **Low large-area cooling** for balance effects.
- Temperature-resistant: stainless steel nozzle, seal: copper ring, stainless steel corrugated tube.
- Compressed-air storage 100 l plus ¾" inlet pipe, valve V9, 12 air regulators and 4 backfitted manometers.

- **Intense cooling of lokal hotspots, two-sided of all staircase electrodes**
- Use of SILVENT laval jet nozzle: core jet with surrounding protection jet.

- **One-sided, large-area jet for cooling of the facile trapezoid zone**
  - \( b_1 > b_2 \) (trapeze)

- **Large-area jet for balance effects**
  - Current discharge zone (*)
  - Head zone (**)
State of Phase Staircase Electrodes Middle Zone

→ Staircase electrodes must amplify the basic current and not counter them
→ Determination of the current with current measuring tongs (primary) and current measuring belt (secondary)
→ Displayed by an oscilloscope

\[
\begin{align*}
B &= \text{basic current} \\
S &= \text{staircase electrodes} \\
R &= \text{resulting current}
\end{align*}
\]

Basic current and staircase electrodes counter each other

Basic current and staircase electrodes amplify each other

Basic current and both staircase electrodes amplify each other
PC: Operating Interface Labview Software

- Calibration
- Heating sequence
- Start
- Display

Set temperature
Actual temperature
Phase cut \(Y_{Ist}\)
### Input Heating Sequence

#### Zone
- **E4**: Bereich 2
- **E3**: Bereich 2
- **E8**: Bereich 3
- **E7**: Bereich 3
- **E6**: Bereich 1
- **E5**: Bereich 1
- **E2**: Bereich 1
- **E1**: Bereich 1

#### Time
- **Dauer [sek]**: 22,00

#### Set Temperature
- **Tset**: 160,00 °C
- **Hyst**: 0,00 K
- **Max**: 0,00 %

#### Max. Phase Cut $Y_{\text{max}}$
- **Tset**: 930,00 °C
- **Hyst**: 0,00 K
- **Max**: 45,00 %

#### Staircase Electrodes
- **P1**: 0,00 %
- **P2**: 0,00 %

#### Number of Heating Steps

<table>
<thead>
<tr>
<th>Dauer</th>
<th>Temp1</th>
<th>Max2</th>
<th>Hyst2</th>
<th>P1</th>
<th>Temp3</th>
<th>Max3</th>
<th>Hyst3</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>22</td>
<td>160</td>
<td>0,00</td>
<td>0,00</td>
<td>160</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>160</td>
<td>0,00</td>
<td>0,00</td>
<td>160</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
</tr>
</tbody>
</table>

**Buttons:**
- **Hinzufügen**: Add
- **Löschen**: Remove
- **Übernehmen**: Accept
- **Abbrechen**: Cancel
Heating Curve Left Zone

set temperature: $T = 930 \, ^\circ C$

$Y_{\text{max}} = 45\%$

time = 22 \, \text{s}$
Video Heating Left Zone

set temperature: \( T = 930 \, ^\circ\text{C} \)
\( Y_{\text{max}} = 45 \% \)
\( \text{time} = 22 \, \text{s} \)
Heating Curve Right Zone

set temperature: $T = 930 \, ^\circ C$

$\gamma_{max} = 70 \%

time = 45 \, s$
set temperature: $T = 930 \, ^\circ\text{C}$

$Y_{\text{max}} = 70 \%$

time $= 45 \, \text{s}$
Heating Curve Middle Zone

set temperature: $T = 930 \, ^\circ\text{C}$
$Y_{\text{max}} = 25\% \text{ bis } 32\%$
$\text{time} = 113 \, \text{s}$
Video Middle Zone

set temperature: $T = 930 \, ^\circ\text{C}$
$Y_{\text{max}} = 25 \% \text{ bis } 32 \%$
time = 113 \, \text{s}
Heating Experiments
Summary

- Conductive heating of form blanks is possible against different literature references
- Example: form blank of a B-pillar
- Blank heating in zones
- Elimination of hotspots and inhomogeneities by compressed-air cooling

Outlook for an industrial application:

- Reduction of the heating time with stronger electrical power supply of the plant
Thank you for your attention!

Thanks also goes to the AiF and the EFB for founding the IGF-Project 16248 N.